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# SECTION II.—GENERAL METEOROLOGY.

## SUMMER TYPES OF RAINFALL IN UPPER PECOS VALLEY.

By Cleve Hallenbeck, Observer.

[Weather Bureau Office, Roswell, N. Mex., Apr. 30, 1917.]

While there are but three recognized primary types of rainfall (cyclonic, convective, and orographic), subdivisions of these three types are necessary to the classification and description of the rains of any one locality. Thus, at Roswell two distinct types of cyclonic rainfall have been observed, one of which is confined to the colder half of the year, while the other may occur during any month, and this latter type can be further subdivided into two groups, one of which occurs during the summer and the other during the winter. All thunderstorms are classed as convective, but they may exhibit slightly different characteristics in different portions of the country; the thunderstorms occurring at this station being different in at least one particular from those observed by the writer in the Mississippi Valley and Eastern States. It seems, therefore, that accuracy in classification could be well served by recognizing subdivisions of the three primary types as long as such subdivisions exhibit individual characteristics.

The summer rains of the upper half of the Pecos Valley may thus be classified as follows:

Convective:

1. Thunderstorms.
2. Local showers.

Cyclonic:

3. Transitional rains.
4. Nonconvective rains.

The first group—thunderstorms—includes all rains of this type, both of purely convective and of cyclonic origin, as the term is generally defined. It might be remarked as an interesting point that the so-called "squall cloud" is seldom observed in thunderstorms occurring at this station. The writer has not once observed this cloud in any thunderstorm during the last two years, although the "squall wind" nearly always occurs. It is possible that in some of the storms the squall cloud may be present but hidden by a curtain of rain.

The second subdivision of convective rains—local showers—includes light rains of brief duration that occur at this station during the warmer half of the year, and which are of convective origin, although they occur at night as well as during the day, less frequently, however, at night. This type is well known at stations near the Gulf coast but, it is believed, is not of frequent occurrence in the elevated regions of the west. These local showers occur when conditions are favorable to the formation of thundershowers, and it may be that some of them are thunderstorms in the first stage of development. The majority of them, however, are not embryonic thunderstorms, as they are frequently observed to die out. As observed at this station, the rain falls from an unusually large cloud of cumulus formation, or from a patch of cloud covering only a portion of the sky, making a "trail" of precipitation of very limited breadth across the country. On one date in 1916 no less than five such clouds were observed at the same time in different parts of the sky, from each of which rain was falling.

The two subdivisions of cyclonic rainfall are believed to be unusual types not generally known or recognized in other portions of the United States, and for this reason they are made the main subject of this discussion. They are primarily cyclonic, but under certain pressure conditions the topographic features of the Pecos Valley give them strikingly individual characteristics, which differentiate them from the usual type of cyclonic rains. These characteristics are outlined in the second paragraph following.

In figure 1 the relative amounts of rainfall and the relative hourly frequency of precipitation from the different types of rainstorms are presented. The left-hand portion of the figure gives the total amount of rain for each hour during the months May to September, inclusive, for the 12 years 1905 to 1916. The right-hand portion gives the total number of times rain has been recorded in each hour over the same intervals of time. It will be seen from this figure (and also from fig. 2) that each of the first three types has its own hours of maximum rainfall. This phase of the subject will be more fully discussed in a later paragraph; attention is invited to these figures at this point to give an idea of the relative importance of the different types of rainstorms.

The two subdivisions of cyclonic rainfall are so nearly alike that there is some doubt as to whether they should be differentiated, and, after noting their points of dissimilarity, they will be treated in the main as a single type. As observed at Roswell, they have the following characteristics in common:

1. The storm always approaches from the south.
2. The wind direction during the storm, and frequently for some time before, is northerly.
3. The barometric pressure, except for diurnal variation, is practically stationary.
4. The rain begins at night and is heaviest after midnight.
5. The velocity of the wind is greater toward the end of the rain than at the beginning.
6. These rains are confined to the warmer half of the year.
7. They occur only when there is a greater than normal pressure gradient from the middle plains region to Arizona.

The two differ in the following characteristics:

1. Group 3 is accompanied by thunder, while group 4 is not.
2. The average time of maximum precipitation intensity of group 3 is 10 p. m. to 2 a. m., while of group 4 it is 2 to 6 a. m.

It should be said that the above-named points are characteristic of the *typical* rains of this class, and not of every one of such rains that occur.

The rains of group 3 are called "transitional" rains because, while they closely resemble those of group 4, they are allied to thunderstorms, and are recorded as such. Their period of maximum intensity of precipitation, as well as their period of maximum frequency of precipitation, is intermediate between that of the noncon-

**Amounts.** **Frequency.**

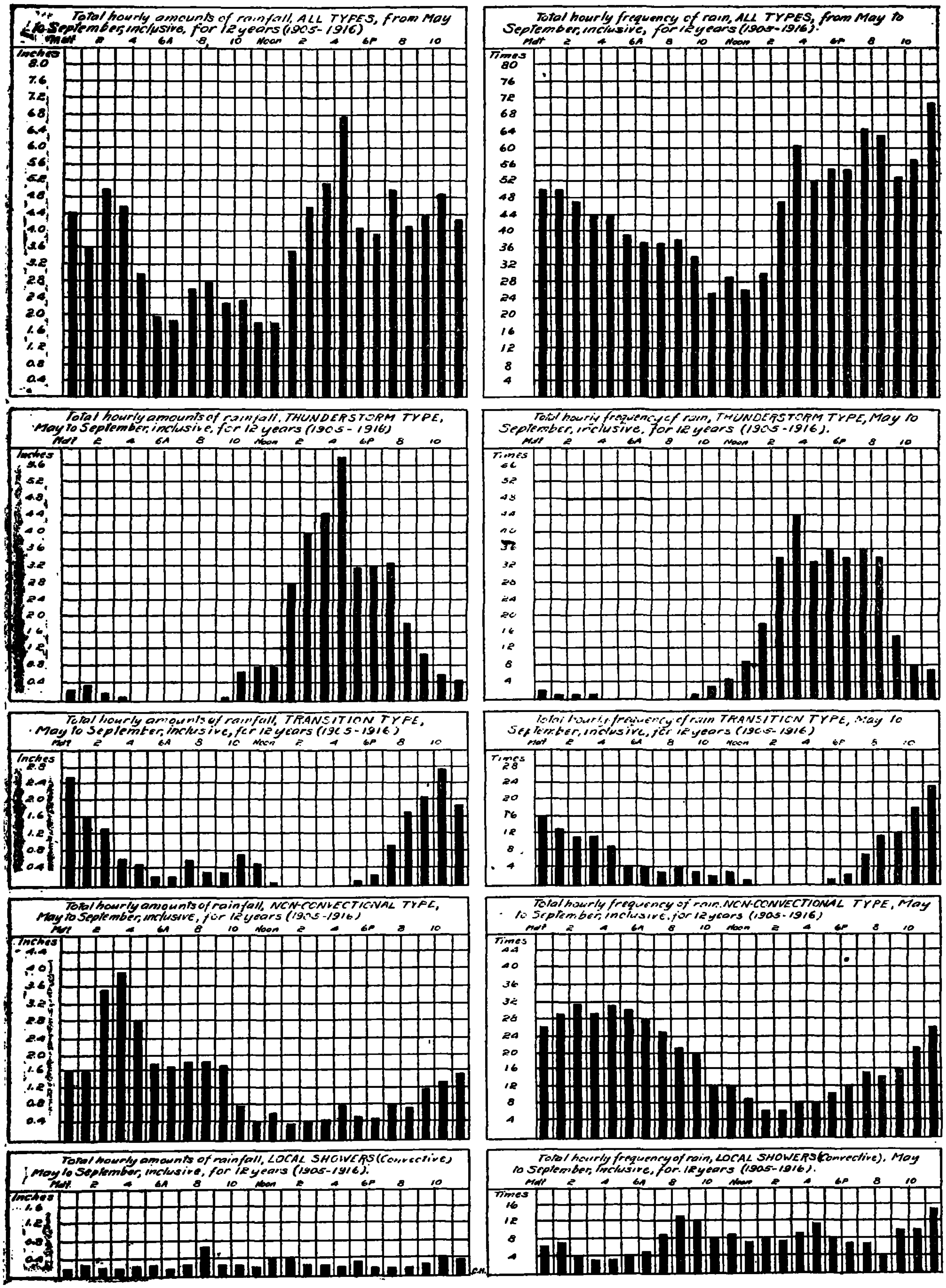


FIG. 1.—Total hourly amounts and total hourly frequencies of rainfalls due to the four types of precipitation distinguished at Roswell, N. Mex., for the 12 years 1905 to 1916 inclusive.

vective rains and that of thunderstorms. The writer believes that these rains begin as thunderstorms farther down the valley—probably in Texas—and by the time they reach this portion of the Pecos Valley they have developed into a form closely resembling the nonconvective rainstorms, with a front 50 to 150 miles in extent, and delivering general precipitation over both the valley slopes. By the time they reach Roswell they have lost their main convective characteristics. It will be shown later, however, that the rains of both group 3 and 4 partake to a limited extent of the nature of both convective and orographic rainfall.

A study of the original reports of cooperative stations in the valley was made in an effort to determine how far to the north and south of Roswell these rains extend and whether they present the same characteristics at other points in the valley than Roswell. Five of the above-named characteristics were verified for other stations as far south as Carlsbad and north as far as Fort Sumner. The third and fifth, of course, could not be verified from the cooperative reports.

The south-to-north movement of the storm was clearly demonstrated in this investigation, and in most cases the beginning of rain showed a regular rate of progress up the valley. In three instances, the beginning of rain was irregular, and in one storm the rain apparently began at the upper end of the valley and progressed southward. In all four of these cases the lower clouds, as observed at Roswell, moved from the south. A few storms of this class have been observed at this station, in which the southerly direction of the clouds changed through easterly to northerly toward the end of the rain, the change being attended by rising barometer.

It was more difficult to ascertain how far up and down the valley the northerly wind extended in these storms, as the observers record the prevailing direction for daylight hours while the rains occur usually at night. Sufficient data were obtained, however, to warrant the assumption that this wind may extend a distance of 150 miles, and possibly farther. For example, the cooperative observer (U. S. Reclamation Service) at Carlsbad, which is the most southerly station in the Pecos Valley in New Mexico, reported that during the record rain storm of August 7–8, 1916, the wind, which had been from the south and southeast, shifted to north at the beginning of the storm, and during the entire time of the rain it blew from the north and northeast. Inquiries sent to intermediate stations brought practically the same information.

In connection with rains of this type, I find such notes as these entered on the local record of this station: "Storm backed against the wind" and "the storm moved from south to north against the wind."

While the weather maps may show a pressure gradient over eastern New Mexico during these rains, the barometer at this station remains practically stationary during the storm and usually for 6 to 18 hours before. No heavy rains were found of record during which the barometer was rising or falling materially.

Tabulated data for 18 of these storms, each of which delivered one inch or more of rainfall at this station, gave the following results: Thirteen began at night and 5 in the afternoon; 15 delivered their heaviest precipitation at night (11 of these after midnight) while the remaining 3 showed no well-defined period of maximum rainfall; in 13 the wind was northerly throughout the storm (in 6, also northerly for some time before rain began); in 3 it remained southerly throughout, and in the other 2 was variable; 6 of the storms were accompanied by thunder; 6 delivered "excessive" precipitation, each time at night and 4 of the 6 times after midnight. In no storm was "excessive" precipitation re-

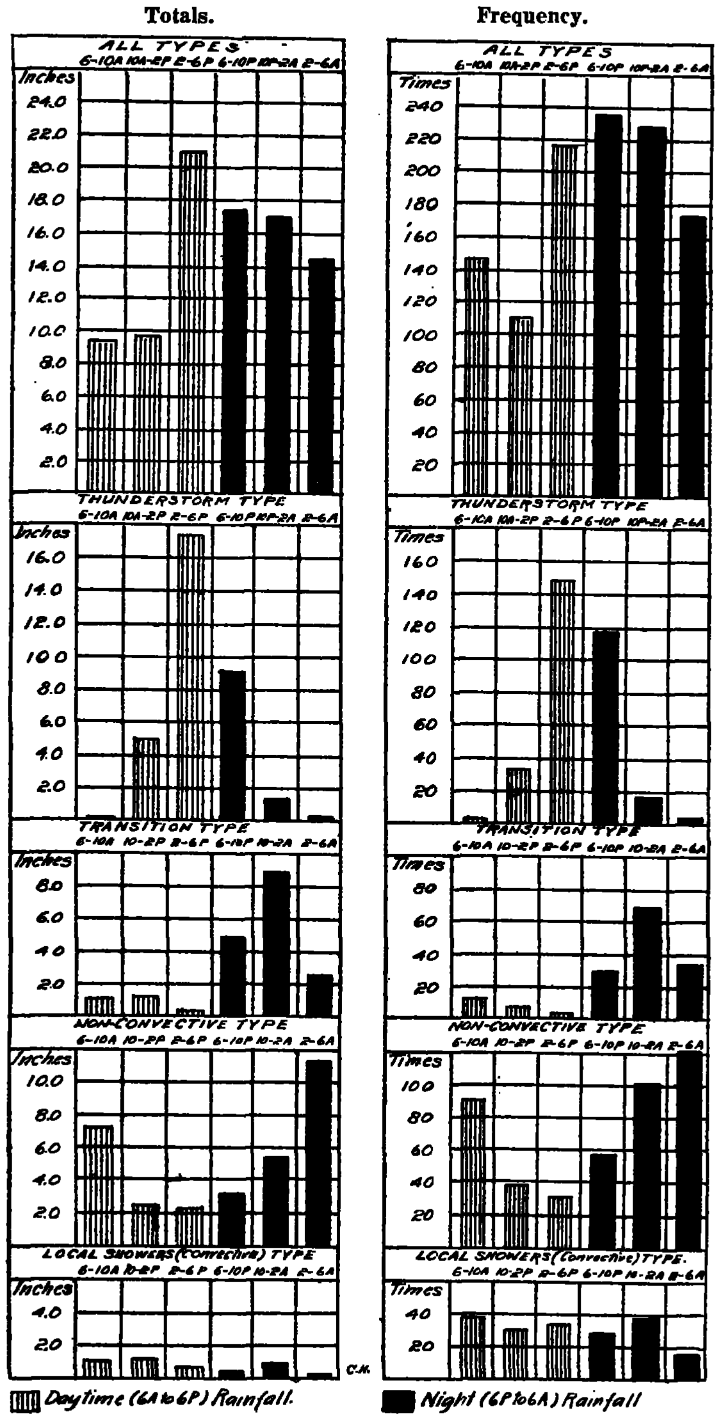


FIG. 2.—Total amounts and total hourly frequencies of precipitation for each of the four types of precipitation, by 4-hour periods, for the 12 years 1905 to 1916, inclusive, at Roswell, N. Mex.

corded with a southerly wind. During 15 of the 18 storms the pressure remained practically stationary at Roswell. All the storms moved from the south.

No rain storms of the type under discussion were found on the local records for the months November to March, inclusive, although they have occurred in April

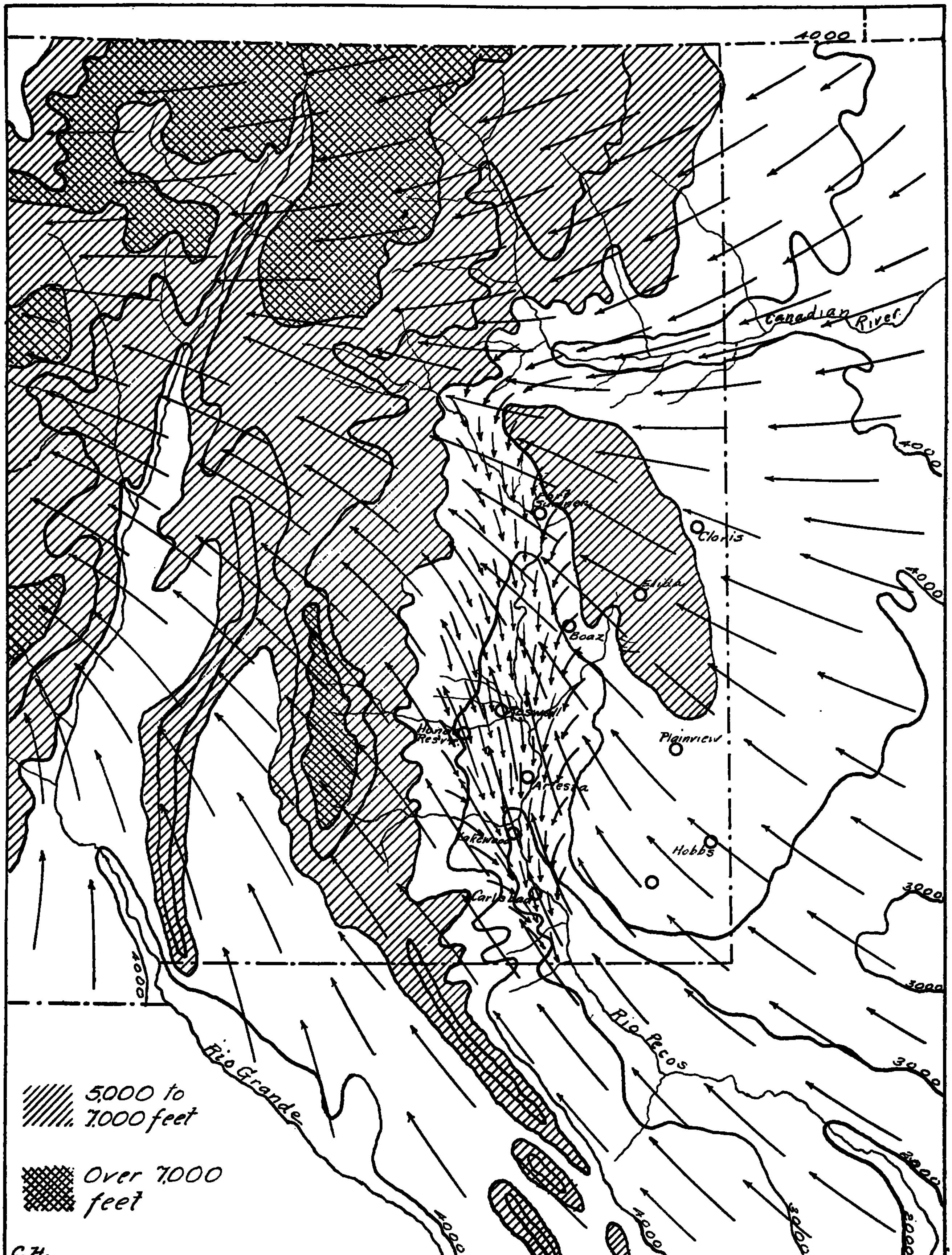


FIG. 3.—Hypsometric sketch map (contour interval, 1,000 feet) of southeastern New Mexico, showing the theoretical air movement across the region when under the influence of a HIGH to the northeast, a LOW to the west, and the Gulf of Mexico. Long thin arrows=direction of lower clouds and the general surface wind. Short arrows=direction of the underrunning night current.

and October, which two months were not included in the data from which figures 1 and 2 were constructed.

Such of these storms as are accompanied by thunder exhibit no other thunderstorm characteristics. There is no abrupt shift in the direction of the wind and no increase in velocity at the beginning of the rain. Precipitation usually begins at a light rate, and is sometimes more than four hours in reaching its maximum intensity. The barograph shows no rise in pressure such as commonly attends a thunderstorm, although two cases were noted where the pressure was very unsteady throughout the storm. The thunder is seldom heavy, and is nearly continuous. In the storms of this class which have been observed by the writer the electric discharges apparently took place above the lower clouds, as no "zigzag" lightning was seen. In the storm of April 16, 1915, the thunder was in the form of what might be called "thunder waves" which moved rapidly from south to north at intervals of 15 or 20 minutes, each "crescendo" being attended by an increasing rate of precipitation and each "diminuendo" by a decreasing rate.

These cyclonic rains may occur when there is no clearly defined HIGH or LOW located as before described, but the most favorable condition is a moderate HIGH to the northeast and a LOW over Arizona. Since a LOW is practically permanent in the Southwest during the summer months, it is only necessary to supply the HIGH in order to have a pressure distribution favorable to such rains. When the HIGH is present the Arizona LOW is apparently deepened, but this no doubt is due to the increased gradient between the LOW and the middle Plains region. In this connection attention is invited to figure 5, which is a composite map of five pressure distributions attending five typical nonconvective rains in the upper Pecos Valley. Even in cases where these pressure areas are not clearly defined there is a greater than normal decreasing gradient from central Kansas to Arizona. The normal gradient varies somewhat during the season, being about 0.17 inch in May and 0.20 inch in July. The average during 18 rainstorms was 0.38 inch, or about double the normal gradient.

Since the barometer at Roswell remains nearly stationary on such occasions, it seems that the HIGH and the LOW are about balanced so far as their influence at this point is concerned. It has been repeatedly observed that if the HIGH be predominant northerly currents will prevail, day and night, both near the surface and at the elevation of the lower clouds, while if the LOW is the controlling feature the flow of air will be from the south and southeast at both elevations, day and night.

*Theoretical explanation.*

With these established facts in view—(*a*) the southerly movement of the rainstorm, (*b*) the northerly direction of the wind, (*c*) the maximum intensity and frequency of precipitation occurring at night, and (*d*) the attendant pressure distribution over the Southwest—the following explanation of these rains is offered:

Unless the air circulation in the Pecos Valley is controlled by a predominant high or low pressure area, the wind shifts from southerly to northerly at night and back to southerly in the forenoon. At Roswell the night shift in summer normally begins at about 9 p. m. and reaches north at about midnight. The daytime shift back to south begins two or three hours after sunrise and reaches south about noon. The shift to northerly is through west and to southerly is through east. The daytime shift from north to south is more clearly marked than the night shift back to north. The diurnal changes are more pronounced in winter than in summer and during the latter season are nearly masked, in the prevailing hourly directions, by the predominant southerly winds.

Since the pressure distribution is such as to maintain, for the time, nearly stationary barometer at this point, the diurnal shifts of the wind occur without material modification. Or it may be said that the southwestern LOW controls the lower air movement during the day, while the HIGH to the northeast controls it at night. The flow of the air upslope toward the LOW would be reinforced during the day by the normal tendency to flow upslope during the day, while at night the outflow from the HIGH would be reinforced by the nocturnal tendency of the air to flow down the valley. This implies a deflection of the outflow from the HIGH contrary to the deflection caused by the rotation of the earth, but it is an observed fact that a HIGH over the middle Plains does produce northerly winds in the Pecos Valley, and materially prolongs the period of downslope winds at night. If the HIGH is absent, southerly winds will prevail throughout the night, with the possible exception of an hour or two in the early morning. This northerly wind, then, during rains of the nonconvective type, is a combination of air drainage and of outflowing air from the HIGH.

Under the particular pressure distribution in question, it seems that at the elevation of the lower clouds the southerly flow of air toward the LOW is maintained throughout the night as well as during the day, as is evidenced by the invariable southerly movement of the lower clouds when these rains occur. The northerly surface wind at night, then, whether it be considered as purely air drainage or as a part of the outflow from the HIGH or a combination of the two, is an underrunning wind flowing beneath the rain-bearing current from the south. The fact that such rains in their typical form occur only when the HIGH is present seems to indicate that in its absence the down-valley wind would not develop against the opposing southerly flow of air, specially in view of the fact that the general cloudiness at such times would retard the cooling of the lower air by radiation, and thereby prevent the formation of a purely drainage current. That this wind is not due to the cooling of the lower air by precipitation or by evaporation of precipitation, is shown by the numerous instances in which it starts some time before rain begins. In the two storms whose precipitation areas are charted in figure 4 this was true. In the storm of July 23–24, 1911, the wind was northerly 10 hours before rain began, and in that of August 7–8, 1916, it shifted out of the south three hours before the beginning of rain, although it did not reach due north until a few hours later.

If this underrunning wind is due to the HIGH, this presupposes that the outflow from the HIGH is cooler than the inflow toward the LOW, which is contrary to the idea that in summer the HIGH is the warmer. It is believed that this special case is an exception to the rule. It will be remembered that the condition being dealt with is essentially a *night* condition, and most pronounced in the latter part of the night. Radiation would be practically unchecked in the HIGH, while in the southerly rain-bearing current, which is, as a rule, cloud laden, radiation would be greatly retarded. Therefore it seems reasonable to assume that at night, and specially after midnight, the outflow from the HIGH is cooler than the air moving up the Pecos Valley. It was found that the average 8 a. m. temperatures, for a number of summer pressure distributions of the type under discussion were 2 degrees to 5 degrees below normal over the area occupied by the HIGH, 1 degree to 2 degrees above normal in the Arizona LOW, and about normal over southeastern New Mexico and western Texas.

It is believed that this underrunning wind is effective in increasing the rate of precipitation, and that it may start precipitation. In several instances the beginning of rain was approximately coincident with the arrival of the northerly wind. In the case of the storm referred to in an earlier paragraph (p. 211) where the rain began first at the northern end of the valley and apparently "backed" southward (the rain clouds moving from the south), the rain and the northerly wind began at about the same time at Roswell, and if the same was true at other stations in the valley, then it seems safe to assume that the northerly wind underran and lifted up the southerly rain-bearing current and thereby started precipitation. If this is true, these cyclonic rains are allied in that one characteristic to cyclonic thunderstorms, and are to that extent convective.

The down-valley wind would, normally, be most completely established during the later hours of the night, and it is during those hours that such rains deliver their heaviest precipitation. It may be that the cooling of the rain-bearing current by radiation plays a part in producing precipitation, since its cumulative effect would become greatest during the latter part of the night.

In the case of these night rains, where the underrunning wind is established in the valley, three causes of condensation are active: the mechanical cooling of the moist air by its ascent up a comparatively steep slope, the further cooling of this air by radiation, and the cooling effect of being underrun and lifted up by the downslope wind. And, since this underrunning current must reenter the prevailing circulation, it may in that way be a fourth cause of condensation, since it is, presumably, cooler than the moist air flowing upslope. All these, acting simultaneously, are sufficient to account for the heavy and sometimes excessive rainfall that this type of storm frequently delivers in the later hours of the night. It will be noted from the above that these rains, while primarily cyclonic, also partake of the nature of both convective and orographic rainfall.

An attempt is made in figure 3 (p. 212) to illustrate this theoretical air movement. On this figure the surface contours are drawn for every 1,000 feet elevation up to 7,000 feet. Higher elevations are not shown, but in the northern part of the State the land rises to 12,000 and 14,000 feet. It will be noted that the mountain range west of the Pecos Valley, while low (6,000 to 8,000 feet) is still 3,000 to 4,000 feet higher than the trough of the valley throughout its entire course, and that this course, which is southeast-northwest in Texas changes to south-north through New Mexico. The normal direction of winds over western Texas and eastern New Mexico, moving in toward a LOW centered over Arizona, should be southeasterly and it is observed that they take this direction over all of that region except the Pecos Valley in New Mexico, and with the possible exception also of portions of the Canadian and Grande Valleys. It is believed, therefore, that the range to the west is effective in deflecting the current to the right as it moves up the Pecos Valley, until by the time it reaches Roswell it is moving from the south (also south at Artesia, but south-southeast at Carlsbad).

It also seems probable that the high mountain ranges in the northern part of the State (12,000 to 14,000 feet) deflect the overflowing air from the HIGH toward the left, so that it moves southward through the col connecting the Pecos and Canadian Valleys. This deflection, as remarked elsewhere, is contrary to the deflection due to the earth's rotation, but nevertheless it is believed that it occurs. The Canadian Valley is very nearly of the same elevation as the valley of the Pecos, while it is flanked on the west and northwest by mountains nearly twice as high as the range which borders the Pecos Valley on the west. This lower range without doubt deflects the wind moving up the Pecos Valley, and it seems reasonable to assume that the high ranges to the north would have a similar effect on the outflow from the HIGH.

In figure 3 a system of winds is represented as flowing toward the LOW from the coast regions of the Gulf and also from the HIGH, this movement being represented by the long arrows. These arrows represent the direction of the lower clouds as well as of the surface wind. The smaller arrows represent the underrunning drainage of air down the valley *at night*, which moves below and in an opposite direction to the prevailing system of winds. This, be it understood, represents the air movements only during rains of the type under discussion. Whether the prevailing southerly flow of air at the higher elevation continues during the night when the weather is clear, is not known. It is possible that similar night drainage may be found, under the proper pressure conditions, in the valleys of the Canadian and Grande, but such is shown here only for the valley of the Pecos.

While this is to an extent an idealized system of winds, the prevailing circulation conforms to the generally accepted theory of air movements under the given pressure distribution, while the northerly wind in the Pecos Valley is in accordance with observed conditions at this and other stations in the valley.

Further with regard to this underrunning wind as a factor in producing precipitation, it may be said that in a number of storms, where the wind was southerly at the start, the rate of precipitation at Roswell began to increase simultaneously with the shift of the wind to the north. In one heavy rainstorm, the wind shifted from northerly to southerly twice during the rain, and each shift was marked by a decrease in the intensity of the rain, which increased again with each shift back to northerly.

Among the numerous storms whose precipitation was charted were a few in which the area of heaviest rainfall was in the Canadian Valley, with a secondary area in the valley of the Pecos (e. g., May 13–14, 1911, May 28–29, 1911), and others where general rain occurred over western Texas and eastern New Mexico, but which was heaviest in the Pecos Valley (Sept. 11–12, 1912; Apr. 24–25, 1911; Apr. 13–18, 1915).

The conclusions reached by the writer—and they are supported by the available data—are (1) that these rains are primarily cyclonic, being produced by the mechanical cooling of warm, humid air moving upslope, under the existing pressure conditions, from the Gulf region; and (2) that the heavy nighttime precipitation in the Pecos Valley is due to the underrunning of the rain-bearing wind by the denser valley drainage, with the probable added effect of the cooling of the saturated air by radiation and by mixture with the underrunning wind.

It is only under certain pressure conditions that air is brought from the Gulf directly over western Texas and eastern New Mexico. When such conditions exist, the moisture-laden air ascends a gradual slope from sealevel to an elevation of 3,000 to 4,000 feet or more. In summer this nearly saturated air is further elevated in the formation of convectional and cyclonic thunderstorms, and this may account for the heavy downpours that sometimes occur over the semiarid portions of these two States. But this does not explain the fact that when these rains are heavy they are often confined to certain river valleys and, under certain pressure conditions, are always heavier in the Pecos Valley than elsewhere.

Referring again to figure 1, it will be seen that the total rainfall at this station is much more irregularly distributed over the 24 hours than that of any one of the three principal types. This is due to the fact that each type has its own period of maximum and minimum rainfall. In figure 1, showing the total hourly rainfall, the three maxima, from 4 to 5 p. m., from 10 to 11 p. m., and from 2 to 4 a. m., mark the hours of maximum intensity of rainfall from the three principal types. The nonconvectional rains greatly preponderate during the hours 9 p. m. to noon, with their minimum amounts and minimum frequency at the time of maximum thunderstorm rainfall. No typical thunderstorm precipitation has occurred at this station, during the last 12 years, between the hours of 4 to 9 a. m., and no nonconvective rain of the transitional type has fallen between the hours of 1 to 5 p. m. Nonconvective rains of group 4 have occurred at all hours of the day, but most of the daytime precipitation delivered by storms of this class has been due to rains that began at night and continued during part or all of the following day.

Figure 2, which gives the amounts of rainfall and the total hourly frequency by 4-hour periods, shows more clearly than figure 1 the difference between the different types of rainfall. The total amounts and the total hourly frequency, as charted, are given in Table 1.

TABLE 1.—*Total amounts and hourly frequencies of rainfall for the 4-hour periods, classified by types.*

| Types. | Total amounts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10 a. m. | 2 p. m. | 6 p. m. | 10 p. m. | 2 a. m. | 6 a. m. | Total. |
| Thunderstorms | 0.02 | 4.93 | 17.45 | 9.14 | 1.68 | 0.08 | 33.30 |
| Transitional rains | 1.15 | 1.24 | 0.12 | 4.67 | 8.74 | 2.51 | 18.43 |
| Nonconvective rains | 7.17 | 2.15 | 2.05 | 3.04 | 5.73 | 11.46 | 31.60 |
| Local showers | 1.08 | 1.15 | 0.88 | 0.55 | 0.99 | 0.32 | 4.97 |
| Total rainfall | 9.42 | 9.47 | 20.50 | 17.40 | 17.14 | 14.37 | 88.30 |
| **Types.** | **Total hourly frequency.** | | | | | | |
| | 10 a. m. | 2 p. m. | 6 p. m. | 10 p. m. | 2 a. m. | 6 a. m. | Total. |
| Thunderstorms | 1 | 33 | 147 | 119 | 18 | 2 | 320 |
| Transitional rains | 13 | 6 | 1 | 32 | 68 | 35 | 155 |
| Nonconvective rains | 93 | 39 | 32 | 57 | 103 | 121 | 445 |
| Local showers | 39 | 32 | 35 | 28 | 39 | 17 | 190 |
| Total | 146 | 110 | 215 | 236 | 228 | 175 | 1,110 |

For all rains during the period covered, a total of 39.39 inches has fallen from 6 a. m. to 6 p. m., and 48.91 inches from 6 p. m. to 6 a. m. During the same periods of time rain has been recorded in 471 hour-periods from 6 a. m. to 6 p. m., and in 639 hour-periods from 6 p. m. to 6 a. m., thus establishing the fact that in Summer both the amounts and the frequency of rainfall at this station are greater at night than during the day. The summer rains of this portion of the United States are essentially daytime rains, and the preponderance of night rains over the limited area occupied by the upper half of the Pecos

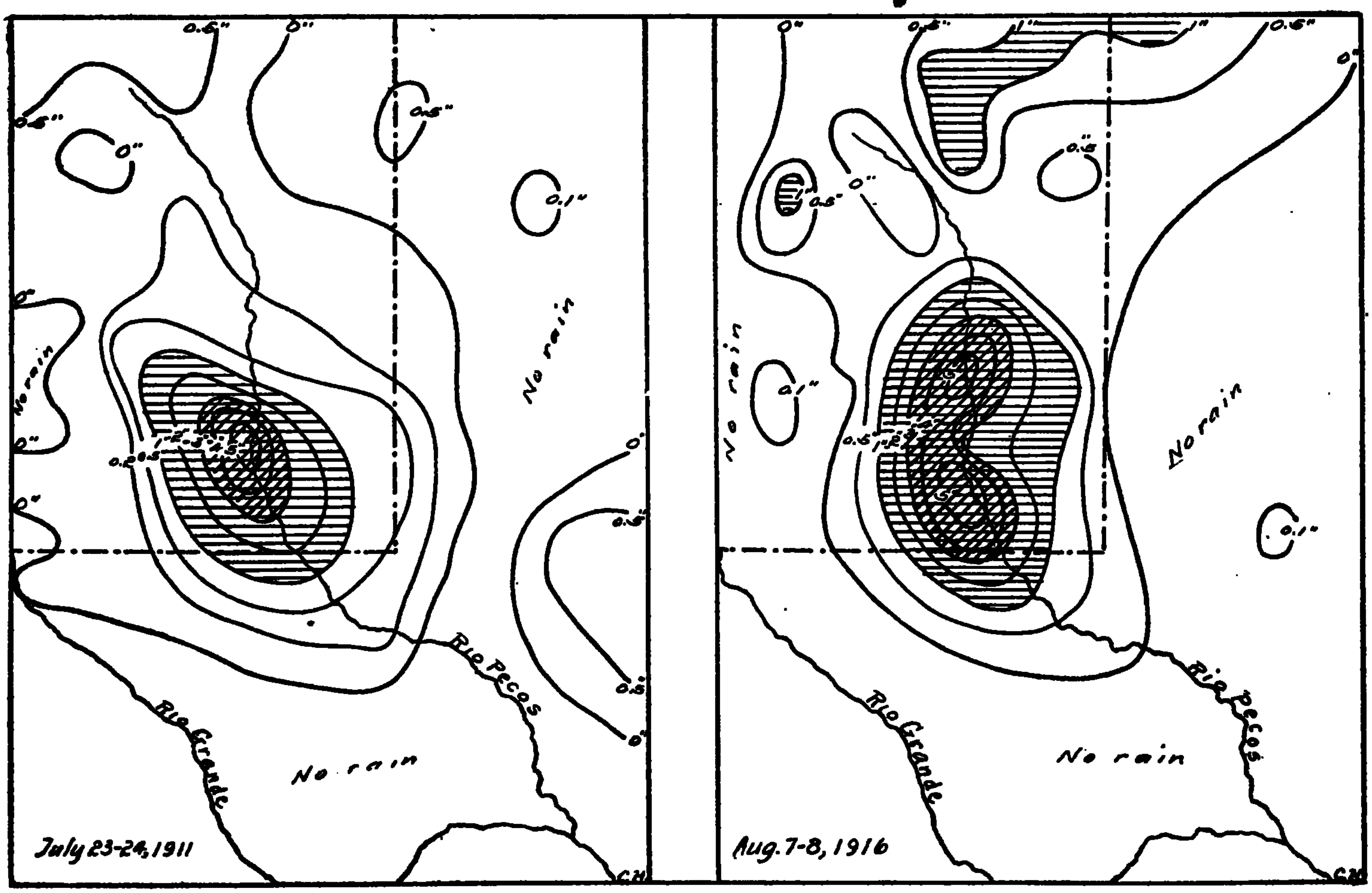


FIG. 4.—Total rainfalls over southeastern New Mexico and western Texas, resulting from two typical storms—July 23-24, 1911 and August 7-8, 1916.

Valley is wholly due to the occurrence of this peculiar type of nonconvective rainfall.

It might be argued that a comparison of the total amounts of rainfall delivered by nonconvective rains with the total hourly frequency indicates that the rains of this type are frequent, but light, while in this discussion emphasis has been placed upon the heavy rainfalls delivered by this class of storms. It is true that as regards the hourly rate of precipitation, most of these rains are light, although more than half of the heavy rains of 1 inch or more at this station were of this type. Precipitation occurring at the rate of 0.05 inch per hour is a light rain, but if it continues at that rate for 24 hours or more the accumulated depth amounts to a heavy rain. Typical storms of this class usually deliver heavy or excessive precipitation for 1 or 2 hours, while the actual duration of precipitation may extend over 12, 24, or 36 hours. In the storm of August 7–8, 1916, for example, "excessive" precipitation was recorded for 2 hours 20 minutes, without a break, while rainfall was recorded for 13 hours before it reached the "excessive" rate, and continued for nearly three hours after it fell below the "excessive" rate. This class of storm owes its importance chiefly to the fact that general precipitation is delivered over the upper Pecos Valley while thunderstorm rainfall, although it may occasionally be heavy, is much more localized.

Figure 4 presents the total precipitation from two typical nonconvective summer rainstorms. These two storms were selected from 18 that had been charted, not because they were extreme types as regards the distribution of precipitation, but on account of the heavy rainfall delivered. These two exhibit an observed characteristic of a number of the heavy rains of this class, viz, the precipitation decreases more rapidly from the Rio Pecos westward than it does to the eastward, whereas one would naturally expect heavy precipitation over the western slope of the valley on account of the tendency of the rain-bearing winds to be drawn up that slope toward the LOW. A few storms, however, carried their heavy rainfall clear to the crest of the range flanking the valley on the west.

Most of the rains that were charted showed a somewhat greater north-and-south elongation of the precipitation area than the two shown in figure 4. In the storms where the heaviest precipitation was in the Canadian Valley, the center of the southwestern LOW was located near southwestern New Mexico, thus bringing the flow of air from the Gulf directly up the Canadian Valley.

*Floods at Roswell due to heavy rains.*

It is an interesting fact that all the serious floods of record in the vicinity of Roswell were caused by storms of the nonconvective type. A number of thunderstorms have delivered heavy rainfall, but in all cases of record they were too localized to cause serious flood conditions. Following is an annotated list of the floods which have occurred since this station was established, the notes being copied verbatim from the local records. The precipitation given is that occurring at Roswell, during the entire storm, which sometimes lasted more than 24 hours.

July 25, 1905, 2.75 inches. Flood in Hondo at reservoir; lowlands of North Spring River under water.

September 1, 1908, 1.12 inches. Hondo bank full; lowlands under water, pastures flooded.

April 25, 1911, 1.71 inches. Pastures and lowlands flooded.

May 29, 1911, 1.66 inches. Hondo out of banks, overflowing through city, lowlands under water.

July 24, 1911, 0.58 inch. High water in Hondo; intake at dam gave way; flood waters also coming down Rocky Arroya; Berrendos bank-full; bridge at Urton's 4 feet under water.

[In this storm the heaviest precipitation was north of the station and between Roswell and the Capitan Mountains.]

June 12, 1913, 1 inch. Flood conditions in Rio Pecos; water 2.7 feet above flood stage.

October 25, 1914, 2.24 inches. No high water in Hondo; Pecos reported bank-full; lowlands along North Spring and Berrendos Rivers under water.

April 17, 1915, 4.91 inches. Lowlands under water; intake at Hondo Reservior gave way, Hondo overran its banks along its entire course, flooding the city (Roswell) with 2 to 3 feet of water on the streets; basements and many lower floors flooded, including Federal building; several residences partly undermined. Cattle companies report thousands of sheep and large number of cattle drowned; fences and bridges swept away; boating on the business streets the popular pastime of the day.

August 8, 1916, 5.57 inches. Streets running curb-full; North Spring and Berrendos bottoms under several feet of water; thousands of birds drowned by over two hours excessive downpour; some bridges gone along the Berrendos, washouts reported on railroad; loss of live stock slight. Flood in Rio Pecos below highway bridge.

There also were a number of serious floods during the years prior to 1905, concerning which no reliable information is available. One, which occurred some time during the early fall of 1904, was of greater magnitude than that of April 17, 1915, during which the Hondo cut a new channel over part of its course through the city.

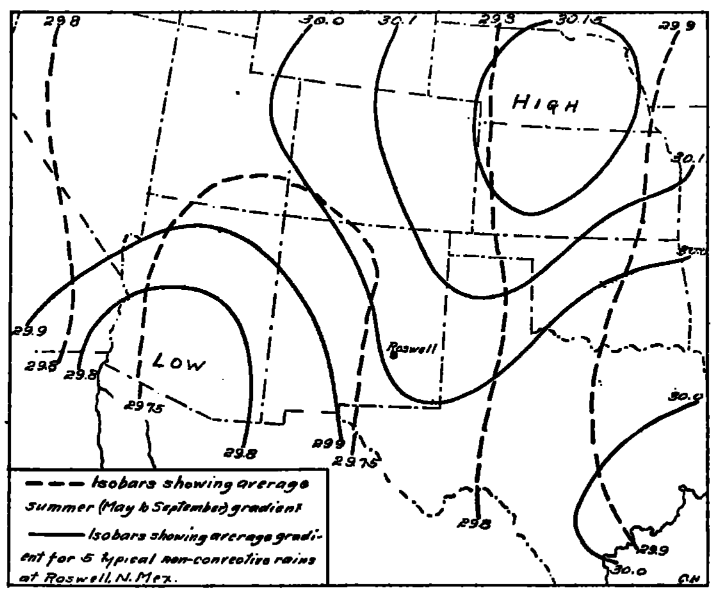


FIG. 5.—Average pressure gradient of Summer (May–September) over the southwestern United States (— — — —) contrasted with the average pressure distribution in the case of 5 typical nonconvective rains at Roswell, N. Mex. (———).

It should be added, in conclusion, that the summer type of cyclonic rainfall is quite distinct from a winter type in the Pecos Valley, which is produced by the admixture of cold air from a winter HIGH with warmer and moister air that had previously moved in from the Gulf region. This class of winter storms rarely yields more than light precipitation, in the form of slow, cold, and disagreeable rain in the late Fall and early Spring, and snow in winter. They are also different from the rains produced by the eastward movement of a LOW across southern New Mexico. This latter type occurs during the Winter and Spring, being of most frequent occurrence in March and April.

Every type of rainfall known to eastern New Mexico occurs at this station in the months of April and October. A number of rains have been noted in these two months that began as the summer type of nonconvective rain, and toward their end degenerated into the first-named winter type.